Key Challenges in Materials and Welding for Application of Steel Structures in Arctic

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ABSTRACT

Fabrication and installation of offshore steel structures in the Arctic region will face some major challenges. Many of these challenges are well known and brought from the North Sea and the Norwegian offshore fields. Exploration in the Norwegian territory of the Arctic has taken place in the southwestern Barents Sea, i.e., in the area free of ice. So far, Snøhvit and Goliat fields have complete installations, Johan Castberg is now under planning. Therefore, there will be a gradual approach towards temperatures lower than -20ºC (the lowest temperature in the current NORSOK standard is -14ºC), which may represent a major challenge for the materials and structural integrity. The design temperature for Goliat is -20ºC, while Johan Castberg will possibly be somewhat lower. Due to the continuous decrease in temperature the further north the field is, welded structures need focus concerning their low temperature properties. Although the initial base metal toughness may be excellent, a severe toughness deterioration occurs normally as result of fabrication welding. The present investigation summarizes results achieved in the steel part of the Norwegian project "Arctic Materials" concerning the low temperature fatigue properties in terms of crack growth, fracture toughness of steel weldments, the toughness scatter and its treatment, constraint corrections, effect of residual stresses and finally, the stress-strain behavior. The results are currently the basis for establishment of design guidelines for steel structures for the Arctic region.

KEY WORDS: Steel; arctic applications; design guidelines; low temperature fatigue; fracture toughness; toughness scatter; constraint

INTRODUCTION

In Norway, research projects on materials behavior at low temperatures have been in progress since 2008 due to an expected increased oil and gas activity in the Barents Sea (e.g., Akselsen et al, 2011; Østby et al, 2011; Mohseni et al, 2012; Welsch et al, 2012; Østby et al, 2012a, 2012b; Jørgensen et al, 2013; Mohseni et al, 2013; Østby et al, 2013; Akselsen and Østby, 2014; Haugen et al, 2014; Mohseni et al, 2014; Wiklund et al, 2014; Hjeltereie, 2015; Kane et al, 2015). In the southwest area of the Barents Sea, north-northwest of the city of Hammerfest, the Snøhvit and Goliat fields are completed and in production. While Snøhvit consists of subsea production units only, the Goliat topside structure fabrication had design temperature of -20ºC. This is below the minimum temperature set in existing NORSOK standards (NORSOK, 2008, 2011, 2014), which covers temperatures down to -14ºC. Lower minimum design temperatures require project specific evaluations. The operator ENI accounted for this during fabrication and installation. At present, the Johan Castberg oilfield, is located about 100 kilometers north of the Snøhvit-field, is under planning. Havis oilfield is another one, to be developed together with Johan Castberg due to the short distance between the two. Several other promising discoveries, e.g., the Gotha/Alta fields and many more, make the situation quite attractive. When moving further north, the temperature falls below -20ºC, which means that the low temperature behavior of the structural steel becomes critical. Thus, the situation calls upon the importance of available adequate standards and guidelines for selection and design of steels for structural application in these areas. Such guidelines are now under development in the ongoing Norwegian project (Horn and Hauge, 2011, Horn et al, 2012; Østby et al, 2013; Horn et al, 2016, 2017).

In the present paper, research results are summarized and discussed in relevance for future design guidelines as basis for robust material and solutions for the arctic region. Included are topics like fatigue behavior in terms of crack growth rates, fracture toughness, toughness scatter, constraint effects, residual stresses, yield strength variation with temperature, and finally stress strain curve shapes.

FATIGUE CRACK GROWTH RATE

Prior to the start of the Arctic Materials projects, data about fatigue crack growth rate behavior at low temperatures for ferritic steel were really scarce and mostly related to model materials (see Alvaro et al, 2014). Consequently, experimental testing was initiated using different microstructures of a 420 MPa plate, including base metal, weld simulated coarse grained heat affected zone (CGHAZ) and the weld simulated intercritically reheated heat affected zone (ICCGHAZ). These experiments have been performed at room temperature and at -60 ºC, always keeping a load ratio R=0.5 (in order to include the